Long-term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping pattern

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Abstract
An 11 years study was conducted to investigate the effects of nine treatments of organic manures (PM: Poultry manure and FYM: Farmyard manure) in combination with chemical fertilizers (NPKSZn) on crop productivity and soil fertility in a wheat-rice experiment in Bangladesh.. Organic manures had direct and residual effects on rice and wheat yields, but the effect of PM was dominant. Plots with FYM plus 75% NPKSZn produced equivalent or higher yields as 100% NPKSZn. The PM direct to wheat produced 12 % higher yield than 100% NPKSZn. After 3 crop cycles, soil pH was increased in plots with PM and unchanged in inorganic fertilizers and FYM. Percent OM (organic matter) was reduced (13 to 19%) with inorganic fertilizers and increased (7 to39%) with organic manures. Percent total N (Nitrogen) was unchanged in OM plots, but reduced in others. Available P (Phosphorus) increased dramatically in PM plots and was reduced in control plots. Exchangeable K (Potassium) was reduced in control and inorganic fertilizer treatments, but was sustained for others. After 9 years, %OM, % total N and exchangeable K were reduced further in inorganic treatment and increased in OM treatments. The soil pH increased in PM receiving treatments.

Key Words
Wheat, rice, organic matter, nitrogen, potassium, phosphorus

Introduction
Rice is the staple food grain in Bangladesh and covers about 80% of the total cropped area accounting for over 90% of total grain production of Bangladesh. Wheat is the second most important food grain and is commonly grown after rice. Over 85% of the total wheat area of the country is preceded by transplanted monsoon rice grown from July to December (Saunders, 1991). Rice and wheat yields have either remained stagnant or declined (Bhuiyan, 1994; Duxbury *et al*., 2000) in South Asia. Modern varieties give higher crop yields but respond to more nutrients than local varieties because of higher amount of potential biomass production. The farmers of the country use only about 102 kg nutrients/ha (70 kg N, 24 kg P_2O_5, 6 kg K_2O, 2 kg S+ Zn) annually (Islam *et al*., 1994), while the crop removal is 200 kg/ha. Consequence of soil fertility is declining. Soil organic matter content in Bangladesh soil is not only poor but it is declining gradually. Studies by Bhandari *et al*. (2002) attributed the reduced productivity of the rice-wheat system to declining SOM, decreased soil fertility, occurrence of nutrient imbalances, and inappropriate fertilizer practices. Previous research considered that the continued use of mineral fertilizers may result in decline of soil quality and productivity, while other studies have indicated positive and no noticeable effects on soil productivity. In most long-term experiments, a combination of mineral fertilizers and farmyard manure has generally given the best crop yield and soil quality (Wang *et al*., 2004; Chalk *et al*., 2003). Singh *et al*. (1983) reported that application of poultry manure alone was about 1.5 times more effective than compost alone in increasing yields of rice and maize as well as building up more available Zn in soil than did compost alone. Sharma and Saxena (1985) indicated that incorporation of poultry manure or FYM in to the soil increased maize yields besides improving soil P indices. Application of poultry manure in Bangladesh is rarely practiced, and the effect of poultry manure application on the wheat-rice cropping pattern or on soil fertility has not previously been documented. The present investigation was therefore, undertaken to observe the performance of the integrated use of poultry manure (PM), farm yard manure (FYM) and chemical fertilizer to sustain soil fertility and productivity in a wheat-rice cropping pattern.

Methods
A permanent plot experiment in the wheat-rice pattern initiated in November 1997 at Wheat Research Centre (WRC), Dinajpur, Bangladesh ($25^0$38' N, $88^0$41' E, 38.2 m above sea level) on a sandy loam on a Old Himalayan piedmont plain. At the beginning of the experiment, the soil was low in available N, medium in

available P, low in exchangeable K, medium in available S and medium in Zn. The soil reaction was acidic. The experiment consisted of 9 treatments laid out in a randomized complete block design with 4 replications. The treatments for wheat were: control (T_1), 100% NPKSZn (T_2), 75% NPKSZn (T_3), 75% NPKSZn+FYM (T_4), 75% NPKSZn+FYM (T_5), 75% NPKSZn (T_6), 75% NPKSZn+PM (T_7), 75% NPKSZn+PM (T_8) and 75% NPKSZn (T_9). In case of rice, the treatments were control (T_1), 100% NPKSZn (T_2), 75% NPKSZn (T_3), 75% NPKSZn (T_4), 75% NPKSZn+FYM (T_5), 75% NPKSZn+FYM (T_6), 75% NPKSZn (T_7), 75% NPKSZn+PM (T_8) and 75% NPKSZn+PM (T_9). For rice, FYM (Farm yard manure) and PM (Poultry manure) were excluded from the treatment T_4 and T_7 to observe residual effects in rice of FYM and PM, respectively. FYM and PM were included to T_6 and T_9, respectively to see the direct effects of FYM and PM in rice. Wheat and rice received FYM and PM in the treatments T_5 and T_8, respectively to evaluate the effect of double application of organic manures per year for each of those crops. One hundred percent rates of recommended chemical fertilizers for both wheat and rice were 26kg P, 33kg K, 20kg S and 4 kg Zn ha^{-1}. However, the 100% recommended rate of nitrogen was 100 and 70kg ha^{-1} for wheat and rice, respectively. Organic manures, both PM and FYM were incorporated @ the rate of 10t ha^{-1} to soil 4-5 and 15 days before seeding wheat and transplanted monsoon rice, respectively. The dry matter FYM was added at 69.52, 128.12 and 58.60 ton ha^{-1} FYM to wheat, both crops and rice, respectively. The dry matter PM was added as 85.69, 162.89 and 77.20 ton ha^{-1} PM to wheat, both crops and as rice, respectively. Chemicals fertilizers were applied using recommended times and methods for the crops. Wheat seed @ 120 kg ha^{-1} was sown at the optimum time (last week of November) every year and the crop was harvested at maturity (Normally 112 days after sowing). Thirty to thirty- seven-day old seedlings of monsoon rice were transplanted on the last week of July every year and the crop was harvested at maturity in the 1st week of November. Weeding was done once for wheat after 1st irrigation and rice 25 days after transplanting. Three irrigations were applied to wheat at 17, 50 and 70 days after sowing (DAS). The rice was grown with natural monsoon rain, but one irrigation was given the 1st week of October (if necessary). Plant protection measures viz. insecticide and fungicide sprays, were not necessary since the wheat crop remained free from insect and pathogen attack. The monsoon rice requited, Marshal, an insecticide @ 1.0 litre ha^{-1} which was applied twice to control stem borer.

The surface soil (0-15cm) was sampled at the beginning from the experimental site and from individual plots after completing 3 and 9 crop cycles and chemically analyzed to determine %total N, available P, exchangeable K, available S, %organic matter and pH. Data were statistically analyzed with MSTAT following the F-test and mean comparisons were made by DMRT at the 0.05% level.

Results and discussion:

Soil fertility

The soil pH, % OM, %total N, available P, exchangeable K and available S content of soil significantly responded to the application of organic and inorganic fertilizers (data are not shown). After 3 crop cycles, soil pH was unchanged in control, only inorganic fertilizers and FYM receiving treatments and increased in PM treatments compared to initial soil test results. The soil pH was increased significantly ($P< 0.05$) in FYM and PM treatments compared to 100% NPKSZn treatment after 9 crop cycles. Considering organic manure treatments, pH was higher in PM treatments than FYM treatments. The mean (mean of PM treatments) soil pH was 0.54 units higher than mean of FYM treatments. The results suggest that organic manures could increase pH of low pH soils by addition of base cations. This result concurs with the findings of Whalen *et al.* (2000) who reported that cattle manure amended soil had significantly higher pH than non amended soil and the pH of Beaverlodge and Fort Vermillion soils increased from 4.8 to 6.0 and 5.5 to 6.3, respectively. Percent organic matter was reduced from 13 to 19% and 18 to 24% in plots where organic manures were not added and increased 7 to 39% and 30 to 62% in plots where organic manures were applied after 3 and 9 crop cycles, respectively. The prominent increasing trends were for plots with PM relative to those with applied FYM. The results indicate that continuous application of organic manure could cause % OM to accumulate in soil although the decomposition rate of OM in high humidity and temperature condition in subtropic region is quick. This investigation is similar to that of Rekhi *et al.* (2000) who reported that an initial low level of OC was raised to a medium level after 3-yrs rice-wheat cropping with the GM or FYM application. Percent total N was unchanged in almost all organic manure receiving treatments except for FYM applied as double application (FYM for both wheat and rice) after 3 crop cycles and increased 11 to 39% after 9 crop cycles relative to initial. In contrast, total N was reduced in the control (25%), 75%NPKSZn (13%) and 100% NPKSZn (13%) plots after 3 crop cycles and further reduced (30 to 35% than initial) in control and where only inorganic fertilizers were used after 9 crop cycles. Reduction of % total N in control and inorganic fertilizers treatments is a consequence of reducing %OM and possibly higher the removal of N

from soil. During the cropping period, soil available P was sustained in 100%NPKSZn, reduced in control and 75%NPKSZn, and increased in organic manures in combination with chemicals fertilizer treatments. It was noticeable that available P content increased dramatically in plots where PM was applied. The results indicate that addition of PM had added higher amounts of P to the soils. After 3-crop cycles, the exchangeable K content was reduced in control and plots where only inorganic fertilizers were added and , it was sustained in plots where organic manures were added. After 9-crop cycles, the exchangeable K was further reduced in control and inorganic fertilizer treatments and increased in organic manure receiving treatments. The available S content was also sustained or even increased irrespective the treatments. The results agree with the findings of Venkatesh Bharadwaj and Omanwar (1994) and Kaushik *et. al.* (1984) who reported an increase in available N, P and K due to FYM application. Also Sharma and Saxena (1985) reported that incorporation of poultry manure or FYM to the soil improved soil P indices.

Grain yields

Grain yields (wheat and rice) significantly responded to added chemicals fertilizers and organic manures in each year (data are not presented). The 75%NPKSZn treatment produced significantly higher yields than control and lower yield than 100%NPKSZn and organic manure treatments during the cropping period. The yields were statistically higher in almost all PM receiving treatments [75%NPKSZn plus poultry manure direct to wheat (residual to rice), double application (poultry manure both in wheat and rice) and residual to wheat (direct to rice)] compared to 100%NPKSZn except in1998-99 and 2002-2003 for wheat and in 1999, 2000 and 2005 during 11-yrs study. Crops were lodged and severity of damage was higher in high input receiving treatments in years that yields were low in PM treatments. The treatments that received FYM [75%NPKSZn plus farmyard manure direct to wheat (residual to rice), double application (farmyard manure both in wheat and rice) and residual to wheat (direct to rice)] produced equivalent or higher yields than 100%NPKSZn. In the 11-yr study, the mean yield was 16 (581 kg ha^{-1}), 11 (361 kg ha^{-1}) and 7% (246 kg ha^{-1}) higher for wheat and 9 (320 kg ha^{-1}), 9 (347 kg ha^{-1}) and 6% (236 kg ha^{-1}) higher for rice for PM direct to wheat, double application and residual to wheat treatments, respectively compared to 100% NPKSZn alone if the abnormal yield in PM as direct to wheat in the 2002-2003 wheat growing season was not considered. The FYM double application gave 6 and 5 % higher yield of wheat and rice, respectively than 100%NPKSZn treatment. The mean yield for wheat and rice was more or less equal for 100% chemical fertilizers, FYM direct to wheat and residual to wheat. The higher yields of crop in organic manures as direct or residual with 75%NPKSZn over only 75%NPKSZn treatment and equivalent or higher yield over 100%NPKSZn was contributed by greater number of spikes/m2 or panicles hill-1 and grains spike-1 or panicle-1. The result suggest that both PM and FYM have potential to increase crop yields as direct or residual by supplementing nutrients to crops and increasing availability of nutrients in soils. The crop yields and nutrient availability were higher in PM plots than FYM plots indicating PM was more effective in producing crop yields and providing nutrients because of its higher nutrient content than FYM (BARC, 1997).

Conclusion

From the experimental results it can be concluded that the combined use of organic manure with inorganic fertilizers performed better than inorganic fertilizers alone to sustain soil fertility and system productivity. PM could be used instead of FYM to get higher yields and to better sustain soil nutrient availability. From the soil analysis results it can be concluded that continuous application of organic manures could enhance the % OM content in soil although the decomposition rate of OM in high humidity and temperature condition in sub-tropical regions is quicker.

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